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Neither does the general belief that they drink train-oil appear to be supported by reliable evidence, and some authors in various localities especially deny it.

I trust that I have presented sufficient evidence to show that the popular picture of the dwarfish Eskimo, dozing in an underground den, keeping up his internal heat by enormous meals of raw blubber washed down with draughts of lamp-oil, is based on exaggeration, to say the least, rather than on actual facts.

THE SIGNIFICANCE OF SEX.

BY JULIUS NELSON.

EXPLANATION OF PLATES I—IV.

The figures have been selected to show as great a variety as possible, that the unity which can be discovered may be a generalization of value. For the sake of clearness they have been drawn with as little elaborateness as possible, and to that extent are diagrammatic.

The following abbreviations have been used:

Z. w. Z.—Zeitschrift für wissenschaftliche Zoologie.
M. J.—Morphologisches Jahrbuch.
Carnoy.—La Biologie Cellulaire, 1884.
Bütschli.—" Protozoa," in Bronn's Classen und Ordnungen des Thierreichs.
A. B.—Archives de Biologie—Beneden and Bambeke.
A. m. A.—Archiv für mikroskopische Anatomie.
A. Z. E. G.—Archives de Zoologie expérimentale et générale.
Kent.—Manual of Infusoria, 1881.
M. z. S. N.—Mittheilung aus der zoologischen Station zu Neapel.
A. A. P.—Archiv für Anatomie und Physiologie.
Flemming.—Zellsubstanz, Kern, und Zelltheilung, 1882.
Q. J. M. S.—Quarterly Journal of Microscopical Science.
A. z. z. I. W.—Arbeiten aus der zoologisch-zootomisch Institut zu Würzburg.
A. z. I. U. W.—Arbeiten aus zoologischen Institut, Universität, Wien.
Haeckel.—" Radiolarien," 1862.
Hertwig.—" Organismus der Radiolarien," 1879.
Claparede and Lachmann.—Études des Infusoires, 1861.
Stein.—Organismus der Infusionsthierchen, 1867, 1882.

PLATE I.

FIG. 1. *Actinosphærium eichornii*—Gruber,[1] Z. w. Z., xxxviii.—The protoplasm is in the form of a net-work with enlarged nodes, many of which bear nuclei in various stages of karyokinesis.

FIG. 2. *Calcarina spengleri*—Bütschli, M. J., xi.—A nucleus surrounded by reticulated protoplasm is shown. It contains one large and several small nucleoli, all

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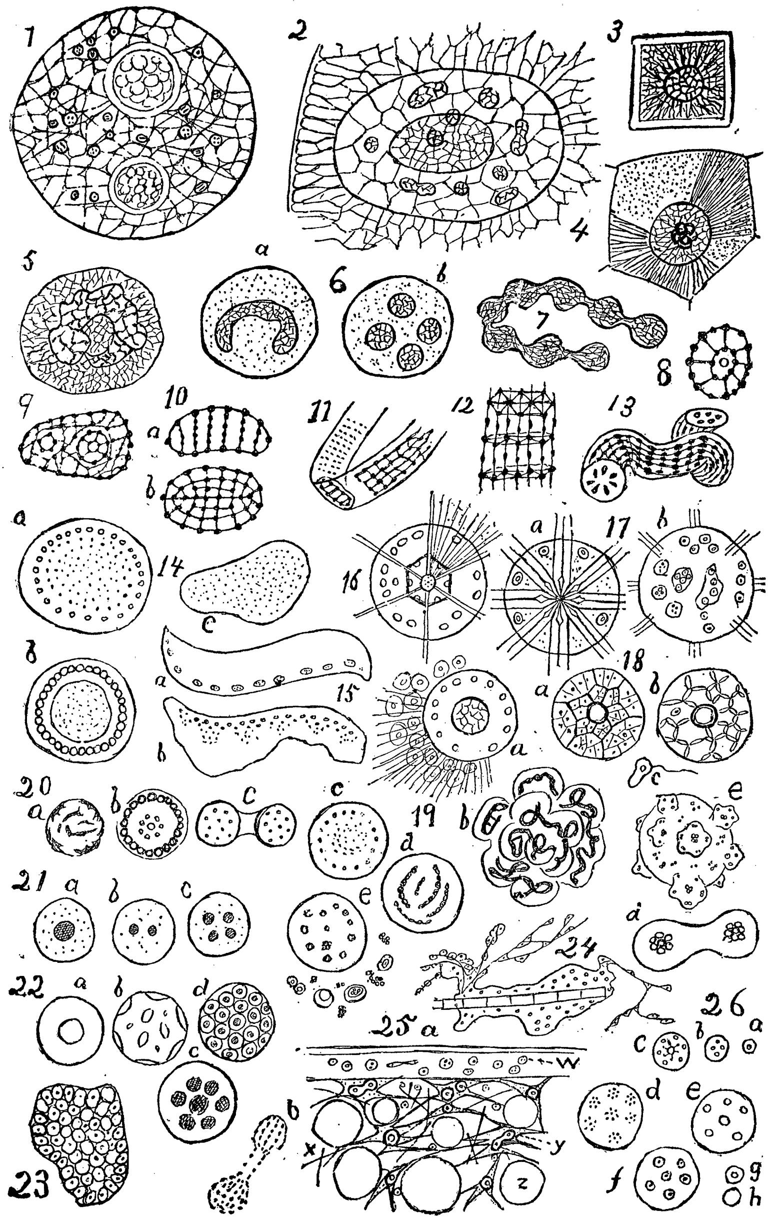
[1] The name following the species refers to the author of the paper from which the figure was copied, and does not necessarily refer to the discoverer of the species.

PLATE I.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having essentially the same reticulate structure. Some of the nucleoli are dividing by simple constriction.

FIG. 3. *Intestinal epithelium cell* of an *insect*—Carnoy, p. 190.—The reticulate nucleus is slung by a fine net-work, whose radial trabeculæ are the more pronounced; they branch towards the periphery of the cell.

FIG. 4. *Intestinal epithelium* from an insect larva—Carnoy, p. 195.—The granules in the cytoplasm have been indicated in some sectors, and the reticulum in others. The heavy nuclear reticulum, containing the chromatin, has contracted under the action of the *chrom-aceto-osmic* mixture of Flemming, and reveals a fine reticulum of achromatic protoplasm otherwise obscured by the presence of the chromatic reticulum (or filament, as the case may be).

FIG. 5. *Giant-cell* from marrow of rabbit—Carnoy, p. 262.

FIG. 6. *Encysted Vorticella*—Carnoy, p. 261.—In *b* the nucleus has divided into four.

FIG. 7. Nucleus of *Stentor polymorphus*—Carnoy, p. 260.

FIG. 8. Nucleus of *Monas vivipara*—Bütschli.—Microsomata of various sizes are united by processes so as to form a regular net-work.

FIG. 9. Nucleus of *Ceratium tripos*—Bütschli.—One of the nucleoli has an internal reticulum; the other is vesicular, having only a *surface* reticulum.

FIG. 10. Nucleus of *Ceratium tripos*—Bütschli.—No nucleoli present. *a* is an optic section from the side, *b* is a view of the ventral surface. The microsomata are strung in a row on each of the dorso-ventral filaments.

FIG. 11. Tentacle of *Noctiluca miliaris*—Bütschli.

FIG. 12. Diagram illustrating the structure of striped muscle—Melland, Q. J. M. S., xxv.

See also 93, *d*—Van Beneden, A. B., iv.—Contraction and amœboid movement accompanied, perhaps caused, by mutual attraction of the microsomata.

FIG. 13. Nuclein filament from a gland-cell of an insect—Carnoy, p. 233.—The chromatic microsomata are arranged in a reticulum imbedded in the surface of the *hyaloplasm filament* (nucleolus).

FIG. 14, *a*. A nucleus of *Amœba proteus*—Gruber, Z. w. Z., xli.—The chromatin granules are largest peripherally. In *b* (Z. w. Z., xl.) there is a differentiation of a large central nucleolus with fine granules from a surface membrane of large, closely united microsomata. At times the microsomata are reduced to so fine granules that only a diffuse staining results.

FIG. 14, *c*. *Chœnia teres*—Gruber, Z. w. Z., xl.—The chromatin granules have grown from invisible points.

FIG. 15. *Trachelocerca phœnicopterus*—Gruber, Z. w. Z., xl.—Like Fig. 14, this cell (rhizopod) is multinucleate. In *a* nucleoli appear in each nucleus; in *b* the nuclei have broken down to the state of free microsomata that divide up finer and finer.

FIG. 16. *Haliomma erinaceus*—Bütschli, after Hertwig.—The central capsule only is shown, with its large central nucleus and peripheral smaller nuclei budded from the central one, which has itself peripheral "nucleoli" that resemble the small "nuclei."

FIG. 17. Central capsule of *Acanthometra*. *a*, Bütschli, after Hertwig; *b*, after Stein.—In *b* the nucleoli have become independent bodies, and are separated by irregular division of the nucleus into individual nuclei, probably for reproductive purposes.

FIG. 18. Central capsule of *Collozoum inerme*—Bütschli, after Hertwig, etc. In *a*

the nucleoli are getting clothed with a definitely bounded plasma. In *b* these new cells or germs have become elongate and arranged in a reticulum like that of Hydrodictyon; later they become free and are expelled as flagellate monads, as at *c*. *d* is a young capsule dividing; the nucleus consists of a group of nucleoli or microsomata. *e* is an older capsule budding.

FIG. 19, *a–b*. Central capsule of *Thalassicolla pelagica*—Bütschli, after Haeckel. *b* shows the nucleus budding; it now has its chromatin in a filament which here and there preserves its reticulate arrangement seen in *a*.

FIG. 19, *c–e*. Capsule of *Th. nucleata*—Bütschli, from Hertwig, etc.—In *c* the chromatin is in a surface layer of microsomata and a central granular mass. In *d* the microsomata are in the form of beaded filaments. In *e* the capsule contains many small nuclei dividing, and outside are similar groups that have probably migrated from the capsule.

FIG. 20, *a*. Nucleus from *Amœba lucida* (multinucleate)—Gruber, Z.. w. Z. xli.—The "membrane" bounding the nucleoplasm is at a distance outside of that in which the chromatin bodies lie. These have irregular processes in *a*, indicating the presence of a reticulum. In *e* the nucleus is dividing; the two daughters are still connected by a bridge of hyaloplasm like that which is seen in Figs. 41, 42, etc.

FIG. 21, *a–c*. Nucleus of *A. prima*—Gruber, Z. w. Z., xli.

FIG. 22, *a–d*. Nucleus of *Euglypha alveolata*—Gruber, Z. w. Z., xl.—*a* shows a central nucleolus, *b* many peripheral ones. In *c* they are massed near the centre; in *d* they have multiplied so as to fill the nucleus, and each has taken on itself a structure similar to *a*. This reminds us of the "germinal balls" of Stein and others.

FIG. 23. Nucleus of *Ceratium tripos*—Stein, filled with germs that are set free to reproduce the mother.

FIG. 24. *Labyrinthula*—Cieukowski, A. m. A., iii. (see Lankester, "Protozoa," Encyc. Brit.).—The plasma in which the simple nucleolus-like bodies live, move, and divide is in the act of digesting a conferva filament.

FIG. 25. A section near the surface of *Sphærozoum neapolitana*—Bütschli, after Haeckel.—A layer of "yellow cells" (symbiotic) lies on the surface. The body is formed of spherical vacuoles, " needles," and a " syncytium" of nucleated plasma masses, united by processes with one another. Compare Fig. 1, also volvox, a reticulum of nerve-cells, and Figs. 8–10, etc. The physiological reason for this structure is probably alike in these various cases. *b* shows a nucleus dividing, the nodes of its reticulum appear as granules. Homogeneous nuclei dividing are often amœboid.

FIG. 26, *a–h*. A nucleus of *Pelomyxa villosa*—Greeff, A. m. A., x.—*a* has one nucleolus. In *c* there are several, one central, and a peripheral set. In *d* each has split up into a group of granules or small microsomata; in *e* these have again united, and in each nucleolus repeats the structure of *a*, and is set free as *g*. *h* is a "refringent corpuscle," formed from *g* by disappearance of the nucleolus.

PLATE II.

FIG. 27, *a–e*. Nucleus of *Klossia octopiana*—Schneider, A. Z. E. G., 2d ser., i.—*a* shows a complex nucleolus budding off smaller nucleoli, which in *c* ultimately become nucleolated; *d* shows nuclei dividing; *e* shows a cyst where the remains of the old nucleus is surrounded by the "spores" that were budded off.

FIG. 28, *a–c*. *Stylorhynchus oblongatus*—Bütschli, after Schneider, A. Z. E. G., iv. —In *a*, a spore-cyst is burst and the spores come out in strings, reminding us of beaded filaments in karyokinesis, also of Figs. 7, 10, *a*, 19, *d*, 31, 41, etc. *b* shows a nucleus budding off spores, and *c* is a spore set free.

PLATE II.

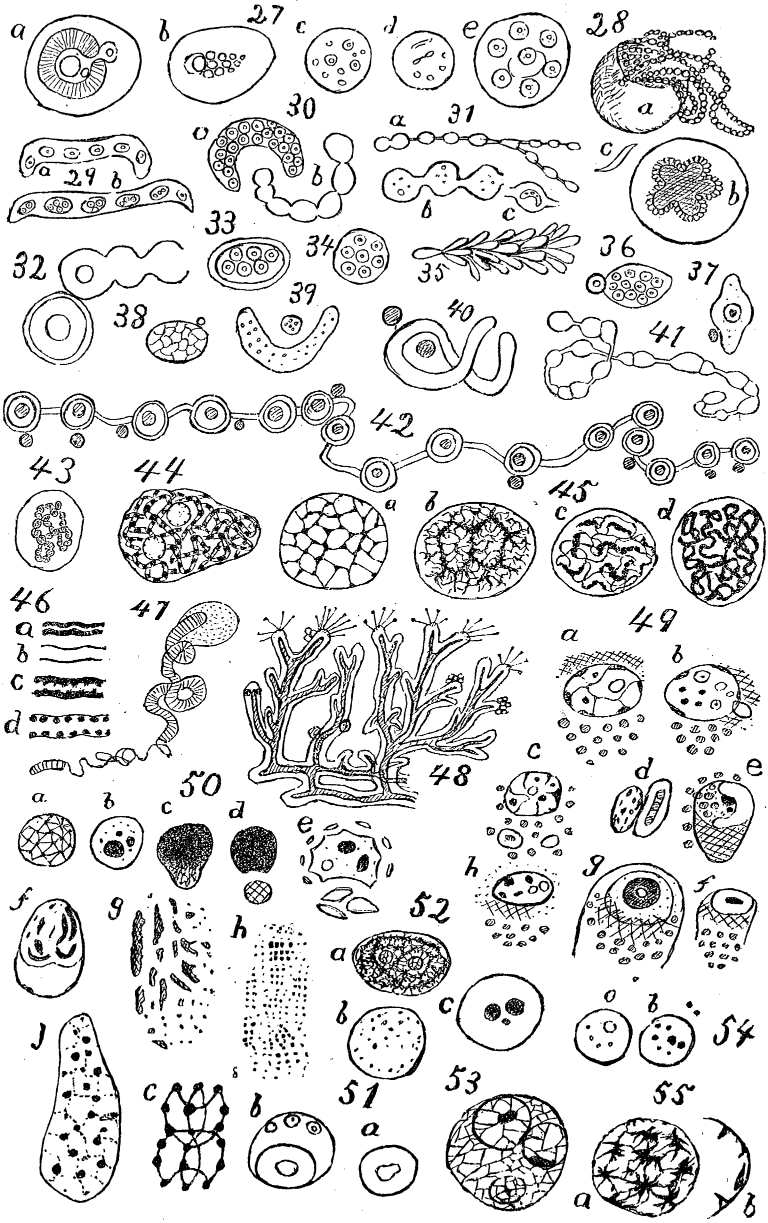
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FIG. 29, *a–b*. Nucleus of *Carchesium polypinum*—Greeff (see Kent, Plate 50).—The hyaloplasm does not appear constricted between the microsomata as in Fig. 31, etc. Each microsoma behaves like a nucleus and gets nucleoli, which themselves become cells like the germs of the "germ-balls." Sexual conjugation is reported as having preceded this state.

FIG. 30. *a–b*, Nucleus of *Actinobolus radians*—Entz, M. z. S. N., vol. v.—*a*, "germ-ball" state; *b*, stentor state.

FIG. 31, *a–c*. *Stentor polymorphus* (nucleus)—Stein (Kent, Plate 50).—The fork in *a* caused by branched budding of one of the microsomata. In *b* and *c* the chromatin has contracted to form itself into the reproductive state of germs.

FIG. 32. Portion of nucleus of *S. rœselii*—Claparède and Lachmann (Kent).—The nucleolus of the part segmented off becomes the nucleus of a new growth.

FIG. 33. Nucleus of *Urostyla grandis*—Bütschli (Kent).—"Germ-ball" state.

FIG. 34. Nucleus of *Acineta jolii*—Maupas, A. Z. E. G., ser. 1, vol. ix. (Kent).

FIG. 35. Nucleus of *Plagiotoma lumbrici*—Stein (Kent).

FIG. 36. Nucleus of *Oxytricha*—Gruber, Z. w. Z., xli.

FIG. 37. Nucleus of *Chilodon cucullus*—Wrzesniowski, A. m. A. V., vol. v. (Kent).—The nucleolus in nucleated and a "paranucleus" resembling this subnucleolus rests against the nucleus.

FIG. 38. Nucleus of *Acineta fœtida*—Maupas, A. Z. E. G., ser. 1, ix. (Kent).

FIG. 39. Nucleus of *Vorticella*—Gruber, Z. w. Z., xli.—Notice a paranucleus on the concave side of the "horse-shoe" nucleus.

FIG. 40. Nucleus of *Leucophyrs patula*—Kent, Plate 29.

Here are seen two paranuclei.

FIG. 41. Nucleus of *Loxophyllum meleagris*—Bütschli (Kent). Microsomata in act of dividing and so forming the beaded filament.

FIG. 42. Nucleus of *Loxodes rostrum*—Wrzesniowski, Z. w. Z., xx. (Kent).—Paranuclei accompany some of the sub-nuclei.

FIG. 43. Cell from *pedal ganglion of Arion*—Carnoy, p. 212.—The nucleus is in the form of a beaded filament in an "open" knot or tangle ("Knäuel").

FIG. 44. Nucleus of *epidermis* cell of an *Orchid*—Carnoy, p. 215.—The nucleus contains two reticulated nucleoli and a chromatic filament in a "close" tangle. The chromatin is in disks, and the intervening hyaloplasm is not constricted, hence the filament is not beaded.

FIG. 45. Nucleus of *epidermis* cell of *Salamander*—Carnoy, p. 219.—In *a*, a coarse reticulum is formed by fusion of the chromatic filament at various nodes of a close tangle. In *b* the connections have been broken, and a continuous filament once more formed, which, by shortening, becomes an "open" tangle, and the phases of karyokinesis follow. The chromatin is diffused throughout the filament. In *c* we see the chromatin withdrawing from the processes of the meshes and gathering in a definite path to form the beaded filament seen constructed into segments in *d*.

FIG. 46. Longitudinal optic sections of various *chromatic filaments*—Carnoy, p. 232.—To show the disposition of the chromatin. In all the chromatin is superficial, forming a thick wall in *a*, thin in *b*, thick with interior processes in *c*, and in *d* all gathered in annular segments distinct from one another.

FIG. 47. A filament dragged out of the nucleus by the section-knife, Carnoy, p. 234, shows that the chromatin is sometimes arranged in a spiral on the wall of the hyaloplastic filament, and may be pulled out like the threads from spiral ducts of plants.

FIG. 48. Fragment of a branching *Acinetan*—Bolton (Kent, Plate 47).—The nucleus runs like an axis through all the stems and branches, and is segmented off into all the buds and spores.

FIG. 49, *a–h. Amphibian pancreas cell*—Ogata, A. A. P. (Phys. Abth.) 1883.—The tissue hardened in warm corrosive sublimate is cut into thin sections and stained successively with *hæmatoxylin*, *nigrosin*, *eosin*, and *safranin*. Gaule, the author of this method, claims that there are two substances in the *cytoplasm*, one *eosinophilous*, the other *nigrosinophilous*. There are also two substances in the *nucleoplasm*, one staining best with *hæmatoxylin* (ordinary *chromatin*), and the other best with *safranin*. The *chromatin* is represented dead-black or heavily reticulated, the *safraninophil* is outlined only; the *eosinophil* is marked with parallel lines, the *nigrosinophil* by crossed lines and dots.

A. The nucleus lies imbedded in cytohyaloplasm (nigrosinophil) well marked on one side. On the other are the *zymogen granules* (eosinophil). A sparse reticulum, several small and mostly peripheral nucleoli (chromatin), and one large nucleolus, the "plasmosoma" (safraninophil), occupy the nucleus. In *b* the plasmosoma is migrating from the nucleus which now atrophies. In *c* the plasmosoma, now in the cytoplasm, begins to develop the two constituents of cytoplasm in its interior. It grows rapidly (*d*) to the size of the old nucleus, alongside which it lies. In *e* it has become still larger, and most of it has become transformed into zymogen granules and cytoplasm. In the centre of the remainder, *f*, a chromatin nucleus appears, which, later, differentiates in its interior, the plasmosoma and other nucleoli, *g*, *h*; and so we are back to stage *a* again.

FIG. 50. Nucleus of egg of *Colymbetes fuscus* (Will, Z. w. Z., xliii.), during ovigenesis and yelk formation.—*a*, reticulated; *b*, nucleolated; *c*, the chromatin growing and enlarging one or more of the nucleoli until all is homogeneous in *d*. It then buds off large and small cells; the former become reticulated and atrophy, the latter become follicle-cells. Then sheet after sheet of the nucleus dissolves off and is transformed to yelk-granules (*e*, *f*, *g*), the chromatin breaks down into granules, and microsomata of a beaded filament in a reticulum enclosing several nucleoli (*h*, *j*), and finally the karyokinetic spindle of the polar globule is formed.

FIG. 51. Nucleus of egg of *Ascaris megalocephala*—*b*, *c*, Van Beneden, A. B., iv.; *a*, Nussbaum, A. m. A., xxiii.—The multiplication of a single nucleolus produces one large nucleolated nucleolus (the "prothyalosome") and several smaller ones; *b*, the prothyalosome alone takes part in forming the polar globules, and its residue copulates with the male pronucleus; *c* is the nucleolus of the prothyalsome highly magnified, seen to consist in this stage of two disks, each of four-beaded filaments (the beads being the chromatic microsomata). Compare Carnoy, see Fig. 124.

FIG. 52, *a–c*. Nucleus of egg of *Pike*—Carnoy, p. 233.—In *a* we have a reticulum and nucleoli. In *b* the reticulum is broken up into nucleoli. In *c* these have fused to three.

FIG. 53. Nucleus of egg of *Nephthys scolopendroides*—Carnoy, p. 237.

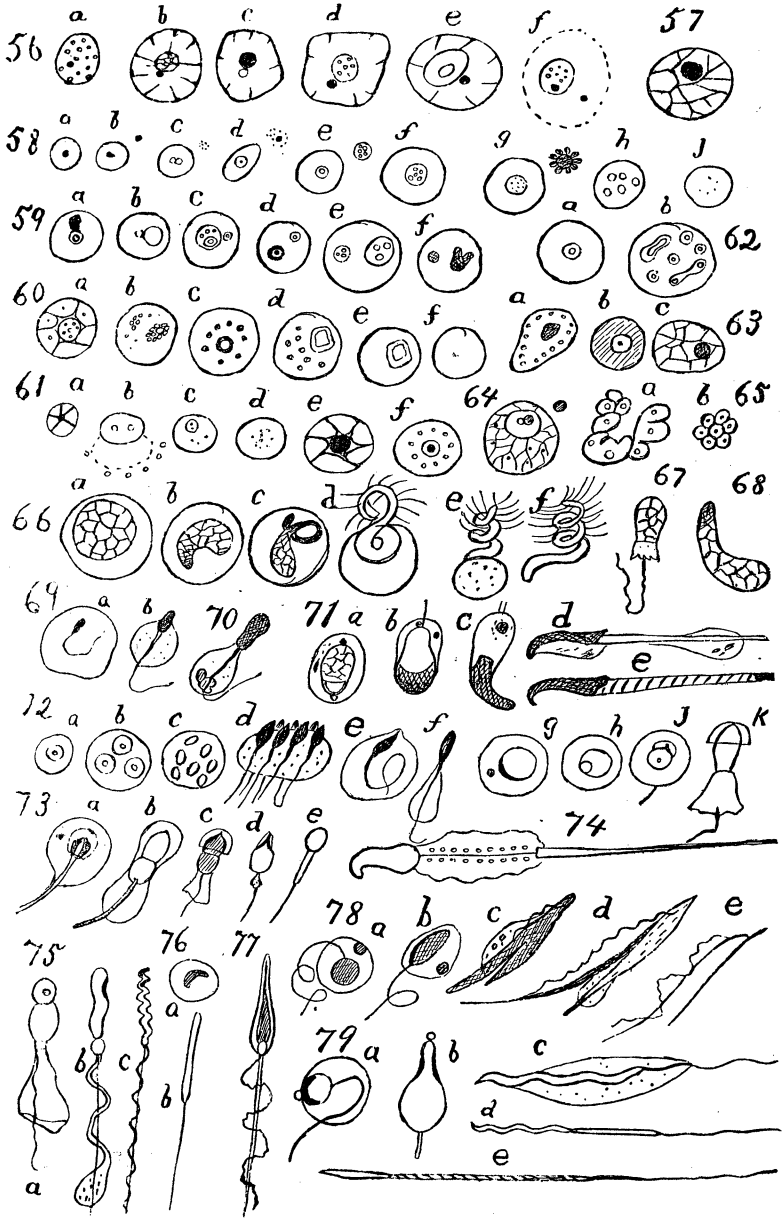
FIG. 54, *a–b*. Nucleus of egg of *Field-Mouse*—Rauber. M. J., viii.

FIG. 55, *a–b*. Nucleus of egg of *Perch*—Rauber. M. J., viii.—In *a* the microsomata are superficial and their processes suggest a reticulum; *b* is an optic section.

PLATE III.

FIG. 56, *a–f*. Nucleus of egg of *Arion* during ovigenesis and yelk formation, Platner, A. m. A., xxvi.—In *a* we see a nucleolus and microsomata and a paranucleus. In *b* the membrane of the nucleus shows the presence of a sparse reticulum, but the microsomata have concentrated to form a reticulated nucleolus, while the old nucle-

PLATE III.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olus is left outside as a paranucleolus. In *c* the nucleolus is homogeneous. In *d* it has microsomata, which fuse to one "nucleolus-nucleus" in *e*. Finally, in *f* the nucleolus has all the structure of the old nucleus of stage *a*. The membrane of the old nucleus now dissolves in the yelk, leaving the paranucleus as a "yelk nucleus."

FIG. 57. Nucleus of egg of *Toxopneustes*—Flemming.

FIG. 58, *a–j*. Nucleus of egg of *Spider*—Carus, Z. w. Z., ii.—In *b* a paranucleus appears, whose changes are as complex as those of the nucleolus. Finally, in *j* we have only a vesicle left.

FIG. 59, *a–f*. Nucleus of egg of larva of *Libelula*—Valette St. George, A. m. A., ii.—The structure of the large nucleolus in *c* reminds us of the entire nucleus of Fig. 51, *b*.

FIG. 60, *a–f*. Nucleus of egg of *Asteracanthion*—Van Beneden, Q. J. M. S., xvi. —The vesicle stage of *f* is reported finally to disappear.

FIG. 61, *a–f*. Nucleus of egg of *Rabbit.*

FIG. 62, *a–b*. Nucleus of *Gonothyraca loveni*—Bergh, M. J., v.—Multiplication of nucleoli by division.

FIG. 63, *a–c*. Nucleus of egg of *Bat*—Beneden and Julin, A. B., i.

FIG. 64. Nucleus of egg of *Anodon*—Flemming, A. m. A., x.—A paranucleus is seen also.

FIG. 65, *a–b*. Nuclei of sexual cells ("primitive ova") of *Rana*—Nussbaum, A. m. A., xviii.—*a* of male, *b* of female. Budding of the nucleus in ovigenesis and spermatogenesis at this stage is often reported.

FIGS. 66–93 illustrate the formation of the spermatozoon from the nucleus of the "spermatid," and points in its structure.

FIG. 66. Antherozoids of *Hymenophyllum*—Carnoy, p. 226.—*a* shows the large reticulate nucleus of the daughter-cell of an antheridium. In *b* the nuclei is elongating, curved, and at its smaller end the net-work of chromatin is changing to the diffuse state. In *d* the pointed end protrudes from the cell and bears the locomotive cilia. This is homologous with the head end of a spermatozoon. The cytoplasm is gradually utilized as pabulum by the antherozoid, the residue remaining stuck to its hinder end *e* (which is finished last), to be finally fully absorbed or thrown off as at *f*.

FIG. 67. Spermatozoid of *Anodonta cellensis*—Carnoy, p. 225.

FIG. 68. Early stage of spermatozoid of *Salamander*—Flemming.

FIG. 69, *a–b*. *Human spermatozoa*, not yet freed from their matrix—Wiedersperg, A. m. A., xxv.

FIG. 70. Spermatozoid of *Elephant*—Weidersperg, A. m. A., xxv.—The head and tail project from the cell, the "neck" or "middle" piece is still growing. In the cytoplasm are the remains of the paranucleus.

FIG. 71, *a–e*. Spermatogenesis of *Rat*—Brown, Q. J. M. S., July, 1885.—*a*, nucleus of spermatid beginning its transformation. At one end the chromatin becomes diffuse, and here also is a *head-corpuscle*. At the opposite end is a *tail-corpuscle*. In the cytoplasm lies a paranucleus. *b* shows the fine *axis of the neck and tail* proceeding from near the *tail-corpuscle*. In *c* the whole nucleus has become homogeneous, elongated and curved, and mostly protruded from the cytoplasm. *d* shows the sperm. nearly completed, a relic of cytoplasm remains sticking where the head and neck join, and another where the tail and neck join. The latter contains the remains of the paranucleus ("seminal granules"). *e* is the completed sperm. The neck shows a spiral structure.

FIG. 72, *a–f*. Sperm. of *Bull*—Kölliker, Z. w. Z., vii.; *g–k*, Brunn, A. m. A.,

xii. and xxiii.—The multiplication of the nucleus of the spermatogonium when the division of the cytoplasm is partially or wholly suppressed, causes several spermatids (and hence spermatozoa) to be united to or in a single cell, and so forming spermatogemmes. *a-d* illustrate this point, which with mammals is not the rule. The concentration of chromatin in one side of the nucleus near a head-corpuscle, the formation of a cap in connection with this corpuscle, is illustrated in *g–k*. The other granule is either the paranucleus or tail-corpuscle. In *k* the membrane covering the middle and hinder part of the head is lost or not separated away like the cap. The "collar" about the neck is the membrane of the old cell.

FIG. 73, *a–f.* Sperm. of *Rabbit*—Brunn, A. m. A., xii.—*a*, after Platner, A. m. A., xxv., shows the paranucleus, the cap and head-corpuscle, the chromatic head enveloping the forward end of the neck-piece or its axis. *b* shows the nucleus in two parts, the posterior portion grows smaller, the chromatin is concentrated in the anterior part of the anterior portion, which forms the head. *e* is from Schweigger-Seidel, A. m. A., i., to show the finished spermatozoon.

FIG. 74. Sperm. of *Mouse*—Brunn, A. m. A., xxiii.—Corpuscles arrange themselves about the axis of the middle piece and build it up, so that in the finished specimen the neck is annulated.

FIG. 75, *a–c.* Sperm. of *Sparrow*—Brunn, A. m. A., xxiii.—Here the cytoplasm spins a filament that winds spirally about the axis, but remains separate from it.

FIG. 76, *a, b.* Sperm. of *Pigeon*—Kölliker, Z. w. Z., vii.

FIG. 77. Sperm. of *Triton*—Schweigger-Seidel, A. m. A., i.—The sinuous filament represents the thickened edge of a delicate membrane, which slings it to the tail like a mesentery. See Gibbes, Q. J. M. S., xix., for same structure in salamander, and Fig. 78, *c–e*, for the frog.

FIG. 78, *a–e.* Sperm. of *Bombinator*—Valette St. George, A. m. A., xxv.—*e* is the skeleton left after macerating away the sarcode.

FIG. 79, *a–e.* Sperm. of *Raja clavata*—Jensen, A. B., iv.

PLATE IV.

FIG. 80, *a–e.* Sperm. of *Branchiobdella*—Voigt, A. z. z. I. W., vii.—In *a* we have a large nucleus, to which is fastened a *tail-corpuscle;* we have also a small paranucleus, but this grows, fastens itself to the nucleus at the end opposite the *tail-corpuscle*, and proceeds to spin a spirallated piece like the middle piece of Figs. 71, 79, etc., but it here has the place of a head-cap, though its functions are probably unchanged.

FIG. 81, *a–f.* Sperm. of *Helix*—Platner, A. m. A., xxv.—Here the nucleus buds off a paranucleus, then concentrates, becomes homogeneous, an axis appears, over its end the nucleus invaginates itself, while the cytoplasm containing the paranucleus spins three spiral filaments; two of these closely invest the axis, the third remains free.

FIG. 82, *a–c.* Sperm. of *Cassiopeia*—Mereschkowski, A. Z. E. G., x.—In *c* the dotted line is a portion of the circumference of the "blastophore," the protoplasmic "cell" which bears the spermatozooids imbedded by their heads over its surface.

FIG. 83, *a–e.* Sperm. of *Cucumaria frondosa*—Jensen, A. B., iv.—Head- and tail-corpuscles are seen. In *e* a middle piece in connection with the tail-corpuscle is seen. The spermatozoon is still unfinished.

FIG. 84, *a–g.* Spermatazoon of *Paludina vivipara*—"hair form" (functional), Brunn, A. m. A., xxiii.—In *b* are seen two tail-corpuscles and peripheral microsomata of chromatin that diffuse in *c*. *f* is the finished sperm., *g* is a bundle of them.

PLATE IV.

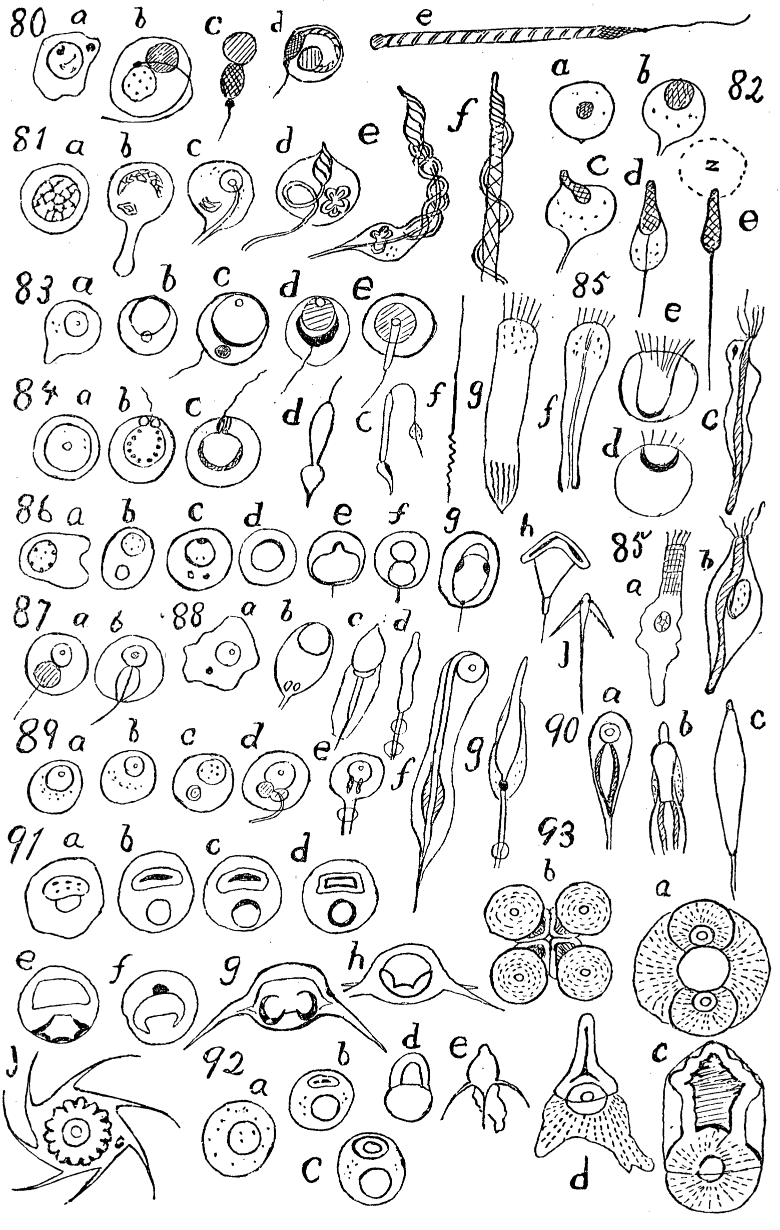
80 a b c d e
f
a b 82
81 a b c d e
c d
z
e
83 a b c d e
85
e
84 a b c d c f
g
f
d
c
86 a b c d e f g
h
85
a
b
87 a b
88 a b c d
j
89 a b c d e f
g
90 a b c
91 a b c d
93
b
a
e f g h
j
92 a b c
d e
d
c

FIG. 85, *a–f.* Sperm. of *Paludina vivipara*—vermiform (not functional), *a–c*, Carnoy, p. 228.—The nucleus here plays no direct part in the formation, but acts like a paranucleus. *d–f*, Brunn, A. m. A., xxiii. The nucleus is here represented as directly concerned. Compare *f* and 84, *g*.

FIG. 86, *a–j.* Sperm. of *Locusta viridissimi*—*a*, *b*, and *h*, Valette St. George, A. m. A., x.; *c–j*, Brunn, A. m. A., xxiii.—Here, as in Fig. 73, the head (*f*) divides into two parts, the anterior of which contains the chromatin.

FIG. 87, *a*, *b*. Sperm. of *Forficula auricularia*—Valette, A. m. A., x.

FIG. 88, *a–d.* Sperm. of *Stenobothrus*—Valette, A. m. A., x.—The middle piece (at least its periaxial portion) is formed directly from the paranucleus.

FIG. 89, *a–g*. Sperm. of *Blatta germanica*—Valette, A. m. A., xxvii.—The paranucleus is reported as formed from a granular mass, and it evidently is built into the "middle piece." In *e* and *g* globules of cytoplasma are seen sticking to the flagellum (neck [middle piece] and tail).

FIG. 90, *a*, *b*. Sperm. of *Agrion*—Bütschli, Z. w. Z., xxi., pp. 402 and 536. *c*, *Hydrophilus*. (*Clausilia*, *Acridia*, *Clythra*, etc., agree closely with Figs. 87, 88, 89, 90.)

FIG. 91, *a–j.* Sperm. of *Astacus*—*a–g*, Grobben, A. z. I. U. W., i.; *f*, *h*, *j*, Nussbaum, A. m. A., xxiii. *j* is view from above.

FIG. 92, *a–e*. Sperm. of *Eupagurus*—Grobben, A. z. I. U. W., i.

FIG. 93, *a–d*. Sperm. of *Ascaris megalocephala*—Van Beneden, A. B., iv.—*a*, Spermatocytes forming from the spermatogonium. The two nuclei are united by the *spindle*. In *b* spermatids have formed, held together in a spermatogemme by a "cytophoral" portion (in which is a "*refringent body*" connected with each spermatid, homologous with paranucleus). *c*, the mature sperm. The nucleus is situated in the head, which is left uncovered by the thin membrane that covers the remainder. The "refringent body" is large, and fills up nearly the entire body. *d*. Here the refringent body is small, the protoplasm about the nucleus in the head, amœboid. The microsomata of the cytohyaloplasm, seen in rows, mark the nodes of a regular reticulum.

FIGS. 1–13, 25, 66–68, 71, 81, 93, illustrate the *structure of protoplasm*.

FIGS. 1, 2, 6, 16–18, 22–34, 49, 59, 66, etc., illustrate the "*individuality*" *of the nucleus* or of its subordinate parts.

FIGS. 13, 14, 17, 19, 20, 28–51, illustrate the different *forms of nuclei*.

FIGS. 8–10, 13–15, 19, 20, 26, 28, 43–47, 49–61, illustrate the *different conditions and morphological structure* the nuclein may assume aside from the changes of *karyokinesis*. Still other examples will appear when *karyokinesis* is considered.

FIGS. 50–64 (exc. 62) illustrate the *structure of the "germinal vesicle."*

FIGS. 66–93 illustrate the *structure of the spermatozoon*. (Only a small piece of the tail has in each case been represented, to economize space.)

FIGS. 36–40, 42, (44?), (49!), (50?), 56, 58, 64, 70, 73, 78, 80, 81, (83?), 84, 86–93, indicate the presence of a *paranucleus*. Other cases will be given under *karyokinesis* and *fertilization*.

I.—Introduction.

"WHAT is the significance of *sex?*" is a special inquiry in the more general field of research included under the head of *Reproduction;* but nearly all the problems of the larger subject must be investigated if we wish to elucidate the more special one. The question presents both morphological and physiological aspects. Thus, we need to know the intimate structure of the sexual cells in the different plants and animals and the modifications this structure undergoes from the time the cells are generated until fertilization is effected. We can in this way compare the ovum and the spermatozoon and perhaps learn whether their functions are alike or different, and in what they differ. But we must also know how they compare with other cells, and are therefore at once compelled to treat the general subject of *Cytology.* This may conveniently be done in the following order: (1) Cell-structure in general. (2) The structure of sexual cells; the ovum (practically the germinal vesicle) and the spermatozoon. (3) The phenomena of karyokinesis. (4) The phenomena of fertilization.

Then in the next place it is necessary to make a comparative study of the methods of reproduction in the groups of living beings, following the phyla of evolution. In unicellular organisms we shall be mainly interested in the various ways in which reproduction is effected and the relation of these to the action of environing circumstances. Here we may see the origin of sex and henceforth trace its evolution. Then as we see how the multicellular individual arose from the unicellular one, and as we trace the evolution of more and more complex forms, differentiating into more and more numerous groups, the relations of the sexual method to other methods of reproduction will gain in interest and be best considered under the heads of *Alternation of Generations* and of *Parthenogenesis.* We shall also be specially interested in following the genesis of the sexual cells during the life-history of each individual, and so be involved in the mazes of *ovigenesis* and *spermatogenesis.* Incidentally *hermaphroditism* should be touched, and finally the morphological side of the question must conclude with a discussion of the significance of the *polar globules* and allied points.

Then on the physiological side, there is a vast and fruitful field both of accumulated facts and promising experiments for future research. The numerical relations of the sexes under fluctuating conditions so comprehensively discussed by Düsing in his memoir on the "Regulation of the Sexual Ratio," first invite our consideration. Next we cannot escape a discussion of the problem of *Heredity*, because this is the very soul and centre of all these other problems; and finally we must necessarily conclude by discussing the doctrine of the *Genesis of Species.*

We thus see that this inquiry is one of vast proportions, and can understand why it is still unsettled, in spite of the flood of speculations that all ages have poured upon it because of its absorbing interest and importance. But all except a very few of these attempts at a solution of the problem of sex are of no scientific and only of slight historic value. We shall only attempt a summary of our *present* knowledge of the subject as a *foundation* for future progress.

The stimulus this kind of research received through the labors of Darwin has not been effected in as great a degree among English-speaking savants as with the Germans. It is desirable that more interest in this subject be awakened among American naturalists, not alone for the sake of national pride, but also because the obscure recesses of this great problem can be illuminated only by the combined labors of many minds.

The earliest thinkers, acquainted only with the highest forms of life, naturally supposed that the interaction of the two sexes was necessary to produce a new being. Some, as Hippocrates and Galen, supposed that the two parents contributed equally and in a complementary manner to this achievement; others, as Aristotle, Fabricius, Harvey, thought that one parent was subordinate in his influence, being a mere stimulus to development. The discovery of the *ovum* and *spermatozoon* gave more definiteness to these theories, and so arose the schools of the *ovulists*, who saw in the spermatozoon a fertilizing element of the ovum, and the *spermatists*, who thought the ovum or the uterus to be a *nidus* where the *spermatozoon* was nourished and developed to the new being. Advancing knowledge dispelled the latter views and modified the former, but now arose the controversy of *evolution* vs. *epigenesis*, and so for a season attention was diverted from the main problem of the significance of sex.

Spontaneous generation once accounted for the presence of the swarms of minuter forms of life, but scientific study, aided by the microscope, showed that these lower forms of life multiplied by methods obtaining with the higher forms, and the doctrine of spontaneous generation was, by Tyndall's beautiful experiments, finally banished from the realm of the minutest infusorial life,—to which, as a last resort, it had been restricted. But, with the establishment of the law that all living beings are derived from pre-existing forms of life, we also learned that another method of reproduction, the asexual (agamogenesis), was more widely used by nature than the sexual one, and increases in importance as we descend the organic phyla,—is, in fact, the foundation on which the latter rests, and out of which it has been evolved as a rare and expensive, but useful, link in *generation*.

It is now a half-century since biology received its organon in the formulation of the *cell-doctrine*. From this doctrine we must start in every biologic inquiry. Stated briefly and in the light of the present, it stands thus: The body of any of the larger plants or animals is a mass of minute units, called *cells*, that are organized in a complex way into different orders of higher units, or parts, known as *tissues* and *organs*. The unity or *individuality* of the organism is secured by the harmonious working together of its organs, like the parts of a *mechanism*, towards simple results for the good of the whole. All living beings, compared as to structure (morphology), naturally fall into groups that are related like the branches of a tree (phylogenetic classification). At the roots we place the unicellular beings, then, as we reach the lowest and least subdivided branches, we find organisms represented by simple aggregations of cells like those which lower down live as independent beings; and, as we rise along the phyla, such aggregates become more and more complex in organization. In the development (ontogeny) of an individual its organization is established in the following manner. We start with a single cell, which produces an aggregation by continued self-division, and then the units differentiate into the tissues and organs, becoming successively more and more complex, so that the embryologic history—leaving out of consideration secondary or *cenogenetic* modifications—is a repetition of the stages seen as we ascend its phylum in the natural system. Such relations as these could have been established only by the actual evolution of living beings along these lines, in the past history of the earth; and this is confirmed by the *paleontologic* record. We are thus convinced that organic beings are *genetically* related, and, therefore, the phenomena of reproduction and the question of sex must be considered in relation to the problem of the genesis of species.

The laws of organization of biologic beings find their analogues in civil and social organizations. Hence we often speak of the animal as the *cell-State.* As civilization progresses and *Society* is evolved, the unit, here the human mind, becomes more and more specialized in its activities, and the individual more and more dependent for his existence and welfare upon the fact that he is *part* of an organism,—the *State,*—which is complexly organized of many interworking and subordinate parts. How wonderful are the life manifestations of a State! and yet nothing is done except by the activities of the faculties present in each mind. The *division of labor* causes each function to be more efficiently exercised; but, what is more important, it is the *form* in which this is organized that impresses us and that makes the *individual.* In a similar way, a man may be said, philosophically speaking, to be only a developed amœba, even as a State is a man on a larger scale.

We are thus enabled to understand what is meant by the *Individual.* This term is purely relative, for in an organism where the subordinate units still retain a large measure of independence, the individuality of the lesser units detracts from that of the larger; indeed, the latter is not thoroughly established until the former is sacrificed, when the lesser units are so mutually dependent as to be mere *parts.* When this stage is reached the existence of the lesser units depends on the existence of the greater unit. Thus, when the organic relations or functions in a man's body are disturbed, not only does the man die (cease to exist) as an individual, but the cells also dissolve into the less highly organized substances of "non-living" matter. *Life* may then mean one or both of two things: 1, the activities of the organism (this is of course a mere summation of the activities of the cells); 2, the *form of organization* of these activities; this is a *relation*, an *abstraction*, but is necessary for the existence of life in the former sense,—*i.e.*, *it makes the individual.* The controversies so often arising about these terms can only be due to a misunderstanding of the cell-doctrine.

There is, however, this difference between the *biologic* and the *social* individual,—the latter can be formed by *association* of units at first independent, while in the former *the cells are always genetically related.* The metazoa arose from the protozoa by a modification in the mode of reproduction by self-division, which caused the daughter-cells to remain united. Now, let all the other phenomena and forces remain as before, these daughters will soon divide again, they will not separate but will go on for a considerable period until an aggregate of cells results, then by the operation of the principles that produce *alternation* of *generations* in separated forms and *polymorphism* in *colonies*, there will follow what we term the *differentiation of tissues*, and lo, a metazoon. In a similar way, *among the Metazoa a multisegmented form must have arisen from one unisegmented by modified budding or strobilation.* Natural selection will account for the preservation of forms, but the cause and origin of new forms lies in the above laws of *organization.* We are now prepared for the next step in this argument. As *self-division* is the only form of reproduction that could give rise to the Metazoa, we understand why this is the mode which alone operates during ontogeny. It is also the usual mode of reproduction among the Protozoa. Once in a while under hard conditions of nutrition, etc. (perhaps so only as to its origin—Weissmann), the protozoan individual, too feeble to fight the battle of life alone, fuses (*conjugation* with a neighbor (sometimes more than one?), and thus reinvigorated goes on in its former way again. Possibly *conjugation* is only one, though the most useful, of several methods by which *rejuvenescence* can be effected; at any rate we can see that by "sexual reproduction" we do not mean a new mode of reproduction contrasted with the asexual mode, but simply *a particular mode of a sexual reproduction preceded by a particular method of rejuvenescence* (conjugation, fertilization[1]). Now when the Metazoa were formed by the non-separation of cells produced by binary division, those cells that required rejuvenescence were set free that they might conjugate, and *this is the origin of the ova and spermatozoa.* All the cells resulting from the repeated binary division of the fertilized egg are *homodynamous*, but all could not leave and be fertilized, because many were needed to differentiate into the various tissues for the good of the whole. Even some of the generative cells had to serve their more fortunate brethren by giving origin to the accessory parts of the *generative tissues* that a few cells might be successfully prepared to perpetuate the species. All the tissues, including the *generative*, are based on a stroma of undifferentiated, "embryonic" cells, capable of dividing as they have in the past, and differentiating into their proper tissue when they have the chance, as in *regeneration* of lost parts. These cells are all the descendants of the original egg, and homodynamous with it and each other as if they were separate amœbæ. But after a certain number of divisions they lose the power of dividing further without fertilization and then they differentiate. Only the cells differentiated in the direction fitting them for fecundation ever get a chance to be fertilized.

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[1] Van Beneden, Archives de Biologie, iv. p. 616.

Possibly this want of fertilization, more and more increasingly felt by the embryonic cells as they continue their final divisions, may explain *senescence;* but so long as we do not understand the nature of senescence in the Protozoa we cannot understand it in the Metazoa.

Growth is due in the Metazoa to the double process of cell-multiplication and cell-growth. May we not say that cell-growth is also partly a result of a reproductive process, and that the cell is a living unit by virtue of being organized? There can now no longer be a doubt of this. We can no longer speak of animals as "evolved from a homogeneous bit of jelly." Cells and the Protozoa and Protophyta in general, may be considered as illustrating as wide a diversity of differentiation and gradation of organization as we see exemplified in the larger units or in the social units (societies and states). We cannot conceive of life without organization. *The homogeneous cannot be called living.*

The cell-wall at first was thought of importance, but soon it was seen that this was a secreted product, and so its gelatinous contents, called *protoplasm*, next became the definition of a cell. But most cells had one or more "nuclei" in them, and this was conceived as a differentiated product of the protoplasm. Continued study of the *nucleus* raised its importance more and more, until at present some eminent cytologists are ready to make it the essential part, and the surrounding plasma almost as secondary as the cell-wall itself. Believing this to be the true view, we are ready to consider,—

II.—The Significance of the Cell-Nucleus to the Problem of Sex.

(*a*) CELL-STRUCTURE IN GENERAL.

Microscopic examination of cells in the living state, or treated by the simple *hardening*, *staining*, and *section-cutting* methods of a few years ago, can give us only a superficial knowledge of cell-structure. With such methods the first step taken was to distinguish the protoplasm as differentiated into the outer membrane or *cell-wall*, the more fluid and granular *contents*, and the generally spherical and central *nucleus*. The last body often carries a *nucleolus;* and nucleus and nucleolus may sometimes be increased in number, or, again, they may apparently dissolve to be later reconstituted. Our next step under this technique was to distinguish a primary and a secondary plasma,—the former the *protoplasm* proper, the latter the *deutoplasm* (paraplasm, metaplasm, etc.), formed by processes of *absorption*, *assimilation*, and *degradation* of the protoplasm. The former is active, *life-substance*, the latter passive, *food-substance*. The protoplasm is more firm and hyaline, abundant near the wall and the nucleus, and forms coarse trabeculæ, traversing and bathed by the deutoplasm. The latter substance is mainly " cell-sap," in which float *granules*, oil-drops, yolk-spheres, etc. The difference in the size of cells is due mainly to difference in the amount of deutoplasm they contain. We are not surprised, therefore, to learn that the yolk of a hen's egg is homologous with a microscopic cell, but we cannot say that it contains no more pure protoplasm than the latter.

The third step was taken as a result of studies of the phenomena of fertilization. The nucleus of the egg, the *germinal vesicle*, often shows a structure quite comparable to that of a "typical" cell, and the fact that it was seen to conjugate with the spermatozoon certainly pointed to its *autonomous* nature; but at first the true import of this conclusion was obscured by theories as to the multicellular nature of the ovum.

Our knowledge of the cell has, owing to improved technique, been wonderfully advanced during the last decade by the labors of cytologists, led by Strasburger and Flemming; and at present the work of Carnoy and of Gaule promises a new era in which the science of the cell shall rise to the dignity of a grand division of biology. We shall treat of *Cytology* only so far as a knowledge of it prepares us to understand the import of *fertilization* as a morphological problem.

No one cell described in detail could be taken as "typical." It would be as absurd as to describe a horse as a typical animal. But the horse has tissues which are similar to those of widely different animals. So with protoplasm; it has a typical structure generally obtaining,—viz., *it is reticulated.* The *reticulum* is easily seen in "multipolar" nerve-cells, but almost any cell, when properly treated, will reveal it. (See Figs. 1–13.) A coarse reticulum has its trabeculæ themselves more finely reticulated. The reason for this structure is obvious. The thin threads of protoplasm are bathed by the cell-sap (the *enchylema*), and so the processes of *nutrition* and of *respiration* take place with rapidity. In the protoplasmic reticulum two elements are distinguished,—the clear *hyaloplasm,* which serves as a matrix for granular bodies of various sizes,—the *microsomata.* The microsomata are formed by the growth or the fusion of exceedingly minute grains, to which the term *granules* may be restricted. Then in the nucleus, when the microsomata grow or fuse to a few larger bodies, they readily come to be designated *nucleoli.* So these terms simply refer to size and not to definite substances, for one and the same substance occurs in all these forms, and there is every reason to believe that several different kinds of protoplasm occur in the form of these microsomata.

Another distinction is also made in that the protoplasm outside the nucleus is called *cytoplasm,* and that forming the nucleus is the *karyoplasm* (nucleoplasm). From this we get the terms cyto-hyaloplasm, cytomicrosomata, cyto-enchylema, or cytenchyma; and, correspondingly, karyo-hyaloplasm (karyaloplasm), karyosomata, karenchyma. Chemically, the *karyosomata* contain "*nuclein,*" which is generally termed "*chromatin*" because of its great affinity for "stains." Gaule believes that he can differentiate two constituents of the karyosomata and two of the cytoplasm. He restricts the term chromatin to a substance having most affinity for *hæmatoxylin,* and gives the term *plasmosomata* to those nucleoli that especially fix *safranin.* The microsomata of the deutoplasm are said to especially stain by *eosin,* while *nigrosin* has a special affinity for ordinary protoplasm (cytaloplasm or cytosomata, he does not distinguish which). (See Figs. 49 *a–h.*)

It is pretty certain that protoplasmic movement is due to the alternate contraction with thickening, and stretching of the fibres of the reticulum. The nodes of the reticulum come closer together in some one direction, and get farther apart in the direction at right angles to this; at the same time the microsomata at the nodes absorb the intervening microsomata. This looks as though the matter of the microsomata was subject to mutual attractions and repulsions, and then we could say that muscular movement is a special manifestation of those varied phenomena of division and fusion, attraction and separation of microsomata seen in karyokinesis.[1] However, this generalization cannot be made so long as we are uncertain whether the hyaloplasm or the microsomata are the primary thing, or whether they are independent but mutually reciprocal. If the microsomata (granules) are primary, then we must assume that the hyaloplasm is an aggregation of a special sort of these granules in a definite way to serve a definite function. From the optical properties of the hyaloplasm this structure must be regular and uniform. Others of these granules differentiate in various directions to serve various functions, and form, by various degrees of aggregation, the different sorts and sizes of microsomata. The primary granules from which all these other forms of protoplasm in the cell are derived must be endowed with the power of *growth*, of *reproduction* by simple division, and of differentiation or variation. They would be affected by stimuli and vibrations travelling in the hyaloplasm in which they live. They should be designated *gemmules*, because of all these properties. The *cell, on this hypothesis, is a gemmule state;* it is a complex organism, with parts structured and differentiated for special ends for the good of the whole. The membranes for protection and osmosis, the reticulum for movement and transmission of sensations, the gemmule for assimilation and reproduction. Degraded gemmules like differentiated and degraded cells form the various kinds of microsomata in the deutoplasm, and build up other parts of the cell. We shall see that the facts of cell-structure, of karyokinesis, and especially of fertilization, lend great weight in favor of this hypothesis. The *gemmules are the idioplasm.* They build up the cell in its peculiar characters and maintain it there. Under the above hypothesis the theory of Nägeli as to the structure of idioplasm will apply to the structure of the gemmule, and not to the reticulum primarily as Nägeli intended. But the discussion of this point belongs under the subject of heredity.

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[1] See Figs. 12 and 93, *d*, and consult Van Beneden, Arch. Biol., iv. p. 343, and Melland, Quar. Jour. Mic. Sc., xxv., July, 1885.

It may be asked, what is gained by putting back the problems of life—of assimilation, of reproduction, and of heredity—one step; are they not as inscrutable as before? Undoubtedly they are, but we gain greatly by such a view as this. We can better understand the cell. Just as we simplified the problem of *life* as applied to the higher animals, by the cell-doctrine, so we simplify by as great a step this protean problem by means of the gemmule hypothesis. We must accurately determine what are the real labors of the gemmule out of which, by organization, the more wonderful phenomena of cell-life grow, and then we shall see that we have spanned by a large fraction the chasm between non-living matter and living matter. The albumen molecule is a very minute thing when compared with the gemmule, and there is plenty of room for one or two *stadia* of organization between, that would, when known, simplify the problem completely. On this hypothesis, also, cells must have a life-history in which they pass through stages of development and stop in various degrees of complexity as mature cells. The more highly organized cells must pass through the stages in which the less highly organized remain; and there is room here also for a *phylogeny* and for *cenogenetic* modification. Finally, the simplest cells we know, must be to some extent modified from the condition in which the original cell was. This must be taken into account in trying to derive "living" protoplasm from "non-living" matter. The first gemmule could arise only by organization of a lower order of life, and the first cell must have been an aggregate of like gemmules produced by binary division of a mother gemmule. Reproduction in this hypothetical first cell we may reasonably suppose to have been effected in two ways,—either by a division of the gemmule colony into two smaller colonies, or by a dissolution of its members when each gemmule was set free to become the progenitor of its own cell-state. When differentiation came in, the primitive mode of reproduction became modified, as follows: A few only of the gemmules were kept undifferentiated for purposes of reproduction. The others had to serve these, helping them to get better chance of food by carrying the colony about by amœboid or ciliary motion; others to give protection; others, to furnish a special breeding-place for the gemmules differentiated into the nucleus; and so on. When the gemmule was set free, it more and more had to be protected by special envelopes, and so arose spores. When all the gemmules free for reproductive purposes went into the spores, the protoplasm remaining after the spores were set free could no longer grow, and hence live, and thus in reproduction by spores, as in gregarines, the mother-cell was left as a *corpse* when this sort of reproduction was exercised. (Fig. 27, *e.*)

But reproduction by binary division still continued, modified first as budding, where some of the reproductive gemmules were pinched off with a share of the cytoptasm. Here we must call attention to the fact that the *individuality of the cell does not depend on the number of idioplasm gemmules in it,* for all these, being undifferentiated, are, as it were, embryonic or *alike* and *mutually autonomous.*[1] They continually grow and divide, and two, resulting from one, do not produce a different kind of effect, but only more work than one. Indeed, the effect produced is not seen until they differentiate, and so present the characteristics of the cell. *This principle is extremely important for understanding the facts of fertilization.* It makes no difference whether the reproductive element set free contains *one or a million* gemmules, except that in the former case it *takes longer* to make as large a cell as the mother; in precisely the same way as it takes longer to raise a hydra from the unicellular egg than it does from the multicellular bud. The reproductive gemmules being now confined to the nucleus, binary division resulted in nuclear division; so far as it was advantageous that a large plasmodium-like cell should be produced, the new nuclei remained and nourished the common cell; and so far as the spreading of the cell over the habitat was of advantage, each daughter-nucleus took its half of the cytoplasm, thus producing cell division. This subject will be continued under the head of Karyokinesis. Continued binary division of the nucleus and the development of the products while the mother-cell remains undivided results in *free cell formation* (at least one variety of this). These cells often play the rôle of spores, and what is of importance when this is the case, the size of the spore is reduced in proportion to their number,—*i.e.*, to the number of divisions. In a number of the monads these spores are so minute as to be visible, only as a cloud of refringent points, under a magnifying power of four thousand diameters. (See *Roy. Micr. Journ.*, April, 1886.) Dallinger saw these points grow until they attained the size of nuclei, then there was differentiated a narrow zone, which increased in width around the nucleus and formed the cell. At the time this zone first appeared the hitherto homogeneous nucleus differentiated microsomata within it. (See Fig. 98, *a–e*.) As the flagellates seem to be the lowest of the forms of life in which all other groups converge, we should expect here the most primitive methods of reproduction. This mode of spore formation follows conjugation: the nucleus spreads by a sort of dissolution through the plasma as in the case of the cyst forms. When the latter is broken, these spores imbedded in a plasma fill it. Have we not here a direct reduction to the gemmule condition, each gemmule being given a chance to start a new cell, *i.e.* a gemmule colony?

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[1] Compare Nussbaum, Arch. f. Mic. Anat., xxvi.

From the simple modes indicated above, we can easily derive the methods of reproduction obtaining among the Protozoa. If the whole or a part of the nucleus segments into spores which remain in a "brood pouch" in the cell-body, and are liberated as motile young, we get the "*germ balls*" of Stein. Compare Figs. 22, *d*, 23, 29, 30, 32, 33, 34. The structures here indicated are similar, but in many cases these nucleated bodies simply represent a stage of development or of kinesis of the nucleus, and are not liberated as spores. Bütschli is inclined to disbelieve in this mode of reproduction, but it hardly seems as if his objections sufficiently disprove the evidence we have of its existence.

If the chromatin, instead of remaining uniformly distributed in the nucleus, gathers into a particular body, which sustains the relation of a nucleus to the old nucleus, we get a *nucleolus*. This is a structure very generally found, especially in highly developed cells. The nucleolus is to be conceived as the primary body and the nucleus as secondary. Before the nucleus can divide the nucleolus must divide; but here we may get multinucleolated nuclei by the multiplication of the latter, while the former remains undivided. The general law of cell-life seems to be to conserve in the centre of protoplasmic bodies a supply of undifferentiated or primary substance (the *idioplasm*), and to surround this by concentric structures that protect it, and serve as organs of relation to the external world. The external envelopes are derived by differentiation of this inmost substance. This idioplasm is continually throwing off centrifugally these secondary substances, and the continued life of the cell depends on its integrity. Reproduction always means that a portion of this substance has been separated from the remainder, and so acts from a new centre. The secondary plasmas are *mechanisms* for effecting such separations, as well as organs for other purposes. *Alt the biological manifestations of cell-life are due to the activity of these organs.* All the idioplasm does is to *grow*, by the growth and continual division of its gemmules, and to *differentiate*, by *organizing* in various relations for the different organs, perhaps accompanied by the chemical degradation of the units. What the chemical processes are that take place in the idioplasm unit, by which it grows and reproduces, must be referred for discussion to the subject of *Heredity*. The above is not an explanation, but simply a statement of the facts of heredity, as we conceive them, in this connection.

The forces active in the gemmule are, of course, the primary cause, and the reason for and explanation of the activities of the secondary plasmas, which activities are, as was said above, the phenomena studied in biology.

We can understand, in this light, how we always have structures and processes that obtain in one stadium of organization repeated in the higher, compound, or derived stadia. For this reason the nucleus is, when far enough developed, reticulated like the cell, and the nucleolus itself often repeats the structure. (See Figs. 2–13.) In the same way as we get three concentric structures simultaneously existing (Figs. 9, 13–15, 19–22, 26, 32, 42, 44, 49, 50–64), we may have a quadruple condition (presenting one or more nucleoli in the nucleolus), seen in Figs. 13, 26, *f*, 27, 33, 51, 53, 56, 58, 64; and possibly Fig. 56 is evidence of a quintuple state. The central body is always capable of generating the whole cell by a differentiation of its chromatin (see Fig. 49), and the central body of this new cell has like powers, and so on indefinitely.

We often have the nucleus or the nucleolus dividing into parts that are of unequal value, thus giving *chief* and *accessory* nuclei or nucleoli, as the case may be. (See Figs. 44, 49, 51, etc.) In this case the chief body only retains the reproductive function, and can, by suitable stains, be differentiated from the accessory bodies. In this way Carnoy and Gaule have shown that such stains as hæmatoxylin and carmine are not tests for chromatin in a restricted sense, but that we must use safranin and methyl green. It is indeed a remarkable property of the idioplasm that it has a special affinity for aniline dyes.

In connection with the segmentation of the chromatin comes up the question of individuality. Is a multinucleated cell a single cell? If we understand that the chromatin is composed of many small units, like the soldiers in an army, we see that it can divide into bodies of various sizes, and these bodies can fuse again, just as the different divisions of an army may combine for any operation and separate once more for other duties. Such phenomena of the multiplication of centres of chromatin activity are illustrated in Figs. 1, 24, 25, 31, 42, and 48, or by a colony of flagellates, of hydroids, or by a tree.

Are all the bodies we see, such as nucleoli and granules in a nucleus, the result of *binary* divisions or of simultaneous segmentation of a single nucleolus, or are they produced by a sort of general dissolution? Conversely, what are the laws by which the different orders of bodies from granules to nucleoli are built up? This question is to a large extent obscure as yet. The phenomena to be explained in this connection are illustrated by Figs. 14, 15, 19, 26, 50–63. Even nuclei fuse (as see Figs. 94 and 97, *c*), and the sexual nuclei.

In some low forms of cells and in higher cells degraded by parasitism, such as yeasts and moulds, the nucleus may never take on the form of a compact body, but be present in the protoplasm in a diffused or granular condition. (See Figs. 14 and 15.) In karyokinesis and in maturation or development of nuclei, there seem to be phases in which this condition is represented.

Finally, we consider those forms of nuclei and of nucleoli where the spherical or elliptical shape is departed from to a large extent. Such are the *filamentous nuclei.* These are usually moniliform, being due to incomplete segmentation and to growth in one direction. (See Figs. 7, 19, *d*, 20, *b*, *c*, 28, 30, *b*, 31, 41, and 42.) In the higher tissue-cells, the *chief nucleolus* is present in this form, often being exceedingly long, and wound about in a way so as to give a reticulated appearance to the chromatin. It has been termed the *knäuel* by the Germans, which term means a *tangle*, usually termed a "skein" in English works on karyokinesis. (See Figs. 13, 19, *b*, 43, 44, 45, 46, *a–d*, 47, etc.) In Figs. 13 and 47 we see the chromatin present in these filamentous nucleoli has been complexly arranged in a reticulum and in a spiral respectively. A cross-section of one of these filaments (mitom of Flemming) cannot be distinguished from a section of a spherical nucleolus of like structure.

[NOTE.—After the above article left my hands an important paper by Altmann ("Studien über die Zelle," Leipzig, 1886) came to my notice. By means of fuchsin staining, followed by a wash of picric acid, a new element, the "*granula*," is brought to notice in the cytenchyma. These *granules* have hitherto been included with the cytenchyma in the general term *deutoplasm*, but Altmann believes they should be elevated to the dignity of an element in the protoplasm. To them Altmann ascribes the function of initiating and sustaining the metabolic or vegetative activities of the cell, while the reticulum mediates the motile functions. Morphologically, they are seen to grow and to multiply by fission or budding, so that he has formulated the law "*omnis granula e granulo.*" He conceives the nucleus and nucleoli to be aggregations of granules, as are also the chlorophyl-corpuscles. (Compare Schimper, *Botanische Zeitung*, 1880 and 1883.) All this falls into line with the gemmule hypothesis, but the function of these granules cannot be so primary as he believes, if we are to credit the evidence obtained from experiments on enucleating cells. (See Nussbaum, A. m. A., xxvi.) Nussbaum found that if he cut an *Opalina* to pieces, the pieces deprived of nuclei continued to manifest movement, but did not grow. On the other hand, those pieces that had nuclei regenerated their lost parts. It is worthy of note that if a new formation was once in process of development, this was completed, even though the piece was enucleated during the process. This can be understood if we suppose that gemmules destined to repair the tissues had already migrated from the nucleus, though, of course, we are not confined to this explanation.]

(*b*) STRUCTURE OF THE SEXUAL CELLS.

In speaking of the sexual cells without distinguishing the ovum from the spermatozoon, it is useful to use the word *gamete*, from which we readily coin another useful word, *gametogenesis*, as including *ovigenesis* and *spermatogenesis*. In the present section we are concerned only with the changes which the nucleus of the gamete suffers after its final division in gametogenesis.

It is well known that in the earliest stages of gametogenesis there is little, if any, distinction between male and female cells; that in many cases the cell boundaries are not distinct, but we have a homogeneous albumen containing scattered nuclei, recalling a *syncytium;* that these nuclei have sometimes been seen to multiply by budding or by direct division; that the nuclei, as they grow, lose their homogeneity, and differentiate a reticulum and nucleoli in their interior, and simultaneously a layer of protoplasm, thin at first, grows out as an envelope about them, much as in Dallinger's *monad.* (See *J. R. M. S.*, July, 1886, and Fig. 98.) When the cells are completed, they multiply by indirect division (karyokinesis), but not to a very great extent, if destined to become ova. In this case a period of growth, of storage of nutriment for the future embryo, ensues, and when this work is completed, the ovum shows its homodynamous nature with the spermatozoon by completing its delayed divisions by the formation of the *polar globules.* Why these divisions are thus delayed will be discussed in its proper place.

If the ovum has its special work to do, division of labor has also given the spermatozoon its special work. For the large and stationary ovum must be sought out and penetrated, and so the enveloping cytoplasm is built up into the proper locomotor organs, which gives the male cell its characteristic and varied forms. We see that the characters which distinguish the male from the female gamete, or *vice versa*, are purely secondary and acquired characters, and, in the absence of these, we would be unable to distinguish sex. We shall endeavor to show that *the chromatin is not sexed*, but probably differs in the two cells by an infinitesimal variation. *So far as our idea of sex implies the differentiation of* MALE *from* FEMALE, *the chromatin is not sexed, but so far as it implies* DESIRE FOR CONJUGATION *with other chromatin differing from it by a slight variation, and likewise filled with a longing for conjugation, it* (the chromatin) *is sexed, but to this idea of sex the thought of male and female is foreign. Male* and *female* are ideas that have arisen in contemplating the different secondary mechanisms that have been evolved for the purpose of effecting conjugation; and these characters are the result of the operation of the same principles that have differentiated a gland-cell from an epithelium-cell.

But, let us see how these secondary or sexual mechanisms differ, and how the nucleus is related to them. We first consider the changes that are suffered by the nucleus of

THE OVUM.

Most of the observations on the *germinal vesicle* (nucleus of the ovum) relate to its behavior in relation to the polar globules, which does not now concern us; for we now know that this is simply the nucleus dividing by karyokinesis so as to become sexually mature, and that, as in ordinary karyokinesis, the successive halves of the nucleus left in the yelk are the homologues of those extruded in the globules. We shall show that they are all *equivalents*, and there is not a separation of "male protoplasm" from "female protoplasm" in a once "hermaphrodite" cell.

When the few observations we have of the germinal vesicle during the period of growth are compared, we are struck by the apparent variety in the different cases. But this variety is probably due in part to a real variety in nature, and in part to the limited and partial knowledge we have acquired. From a comparison of Figs. 50–64, we may gather the following general features:

1. There is a richness of chromatin development resulting in great increase in size of the nucleus.
2. There is a considerable number of nucleoli developed.
3. A large portion of the chromatin is broken down and transformed into yelk. (See Fig. 50.)
4. The boundaries of the nucleus are often broken down or obscured; if not, they remain extremely distinct, enclosing a large cavity comparatively free from chromatin, and hence the name germinal *vesicle*. But with either change we find that one of the nucleoli has taken on functions that are probably nuclear in nature, and this has given countenance to the notion that the germinal vesicle may not be a nucleus, but is a cell. Such an assumption of the nuclear functions by a chief nucleolus is repeated over and over again in gland-cells, as in Fig. 49. We thus have a chief nucleolus or *germinal dot* and one or more paranucleoli. The latter simply break down, while the former furnishes the chromatin that divides in the polar globules, and at last conjugates with the male pronucleus; so that we always have a mass of the proto-substance conserved to carry on the existence of the gemmule colony, however much of the chromatin may be used for other purposes, and this reproductive substance is always conserved in the centre of the mechanism, surrounded and protected by at least two envelopes. If the nucleus buds, it produces *paranuclei.* Perhaps this is only a peculiar method of giving off nutritive substances to the cytoplasm. We must here observe that paranuclei, wherever found, are not necessarily homologous structures, either if more than one be found in the same cell or still less where we deal with phylogenetically

widely separated cells. When the germinal dot enters upon its activities as a nucleus it passes through the stages of differentiating a reticulum and nucleoli of different kinds in itself, as we shall see under *karyokinesis.*

(*c*) THE SPERMATOZOON.

When the last division of the spermatocytes has taken place, the nucleus is practically ready for conjugation; hence, that its chromatin may meet the chromatin of the ovum, the secondary or *achromatic* structures of the nucleus transform themselves together with the cytoplasm (which seems to play a more passive part), into the suitable mechanism for effecting the transfer. In most cases the resulting form is filamentous, and has a spiral structure in some part. (See Figs. 66–93.) In such highly complex spermatozoa we may distinguish the following parts:

An outer *membrane*, which is perhaps the relic of the cell-membrane. A *head-cap*, posterior to which lies the *chromatin.* An *axial filament*, which may be taken as a sort of skeleton. (See Fig. 78, *e.*) Finally, there is a medullary sheath, best, sometimes only, developed in the "*neck*" or middle piece of the spermatozoon. This sheath is often composed of two or three bands that have been spirally twisted in opposite directions around the axial filament. Often one of the three is free and hung by a delicate mesentery, and thus may propel the spermatozoon like a screw. In the development of these parts, we first see the nucleus change its shape and become homogeneous, then the axial filament is seen stretching away from the nucleus and pushing the cytoplasm before it posteriorly as the nucleus does at the anterior end. The achromatic part of the nucleus is usually present as a paranucleus (see karyokinesis, Fig. 123, also Fig. 81), which in some cases is directly converted into the medullary sheath. Paranuclei (or granules) of a different sort are often present, and may have something to do in building the axial filament. All growth takes place in the neck just behind the head; and from this point the tail end is gradually pushed out as a completed structure. These accessory parts having accomplished their work of transferring the chromatin, which is to form the male pronucleus, are lost or dissolved in various ways. The chromatin is the essential substance, as we shall learn under "*Fertilization.*"

The development of the spermatozoa in the special cases may be learned by a study of the figures (Plate IV.) with the accompanying explanations. We could now pass on to the subject of fertilization did we not have connected with this phenomena another series of phenomena that can be understood only by reference to the facts of "cell division," to which we next direct our attention.

(To be continued.)

DESCRIPTION OF A NEW SPECIES OF DIPODOMYS, WITH SOME ACCOUNT OF ITS HABITS.

BY F. STEPHENS.

Dipodomys deserti STEPHENS, n. s. Desert Pocket-Rat.

LARGEST known species of the genus. Length, head and body, 5.2 inches; tail vertebræ, 7.7 inches; hind foot, including claw, 1.9 inches. Color above pale yellowish brown, fur plumbeous at base, showing through the tips enough to give an ashy tinge. Below, white. Fore legs from elbow, and hind legs, in front, from knee, white. Tail, at base, on sides, below, and the tip, white; above, pale brown, becoming plumbeous towards the white tip. Indistinct white spot over the eye, another behind the ear, which extends across the shoulder to the white underparts. Indistinct white band across the hips. Indistinct darker spot at base of whiskers. Soles of hind feet nearly white. Type No. 314. Female, June 29, 1886. Mojave River, Cal. Deposited in the National Museum.

Habitat, Mojave and Colorado Desert regions of Southeastern California.

COMPARISON OF THE SPECIES.

Dipodomys deserti.	*Dipodomys phillipsi.*
Size large.	Size small.
Color pale, markings comparatively indistinct.	Color dark, markings distinct.
Eyes moderately large.	Eyes very large.
Soles of hind feet white in the young, indistinctly brownish in the adults, perhaps due to soiling.	Soles of feet dark brown (same color as upper surface of tail).
Spot at base of whiskers merely darker than surrounding parts.	Spot at base of whiskers nearly black.
Mastoid region enormously inflated.	Mastoid region comparatively moderately inflated.